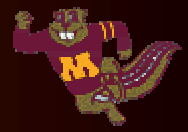
User Interfaces for a Robotic Distributed System



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*** MTS Inc.**
**** Dahlin Consulting Inc.**

Rangers and Scouts

Heterogeneous robotic team

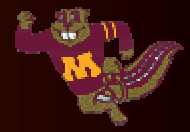
Rangers

- **General purpose off-road robots**

Scouts

- **Custom portable sensor platforms**

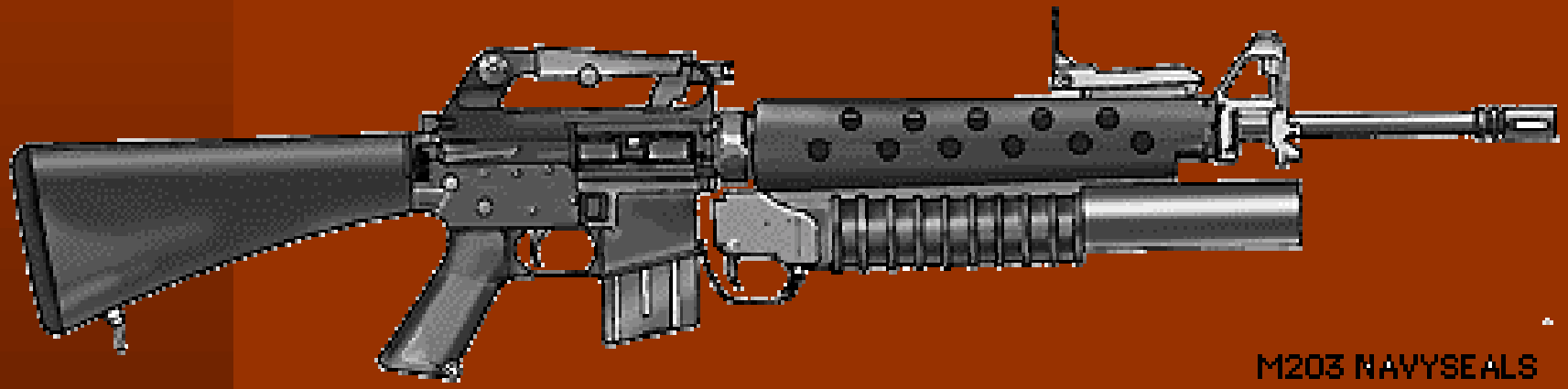
Scout Project Mission

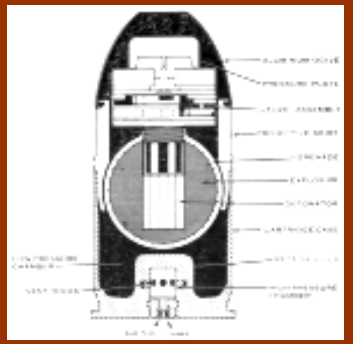


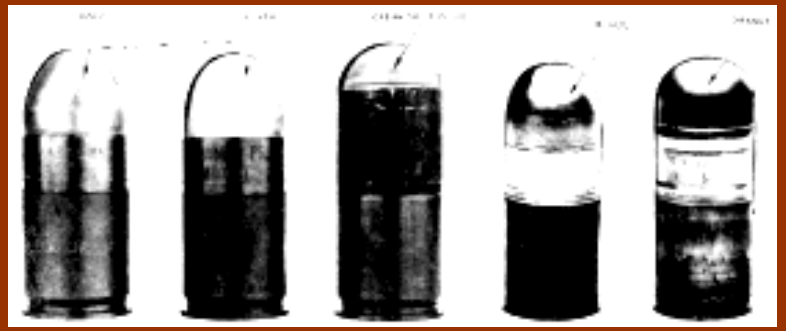
- **Develop distributed robots with various mobility and sensory modes for exploration of structures in urban warfare.**
- **Use standoff delivery via grenade launcher**
- **Data fusion and analysis are to be at a remote operator station**
- **Operate by remote and/or autonomous control**

Motivation

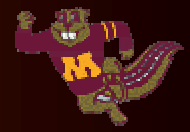
M203 Grenade Launcher on M16





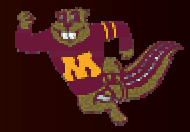


Dual Use Opportunities



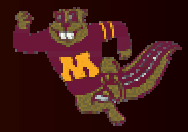
- **Law Enforcement Agencies:**
  - **Hostage situations**
  - **Counter terrorist units in large cities**
  - **Fire and rescue**
  - **Disaster relief**
- **Coast Guard: vessel boarding and search**
- **FBI Fugitive Task Forces, FBI Crisis Response Team**
- **NASA space exploration programs**

FBI Applications



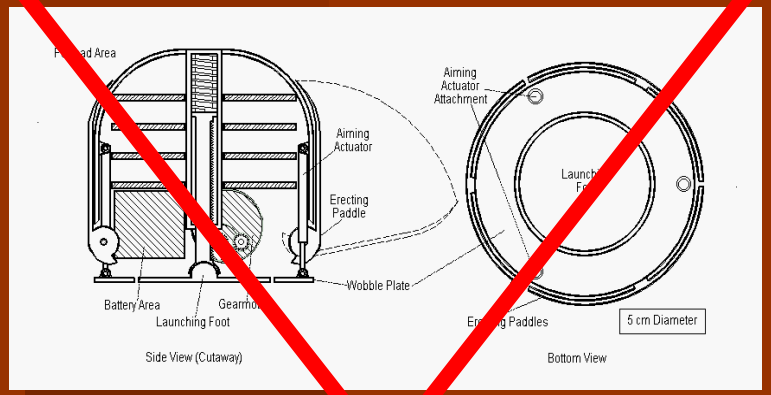
- **FBI Crisis Response Team (CRT), Quantico VA**
  - **National Counter Terrorist, Hostage Rescue Operations**
  - **CRT is a low volume, custom hardware user**
  - **CRT provides real-time learning and development grounds in a non-combat environment for distributed robotic systems**
- **FBI Fugitive Task Force Units**
  - **Similar environment to foot soldiers engaged in Military Operations in Urban Terrain (MOUT)**
  - **Single scouts, remotely controlled can reduce risk of entry to urban spaces**

United States Special Operations Command

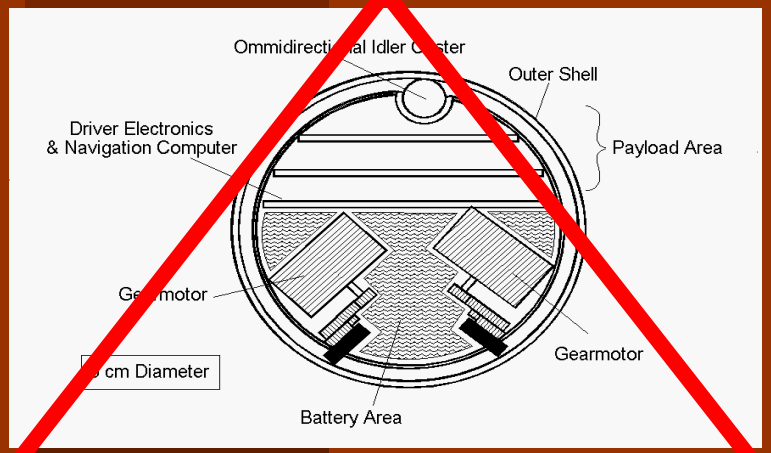


- **Provide situational awareness for closed, hazardous, or restricted access spaces**
- **Provide single scouts for individual soldiers entering specific compartments or rooms.**
- **Distributed scout deployment prior to large scale building entry (MOUT)**
- **Scouts can be mission adaptable and reconfigurable as a MOUT expendable sentry: place and monitor, re-locate or patrol as required, abandon if overrun (self-destruction optional).**

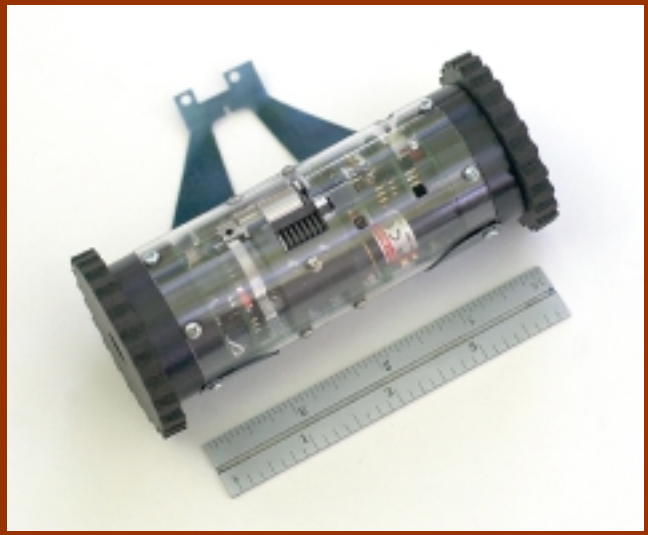
Redesigned Scout



Grasshopper

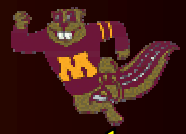


Rolling Ball



Scout 2000

Technical Innovations

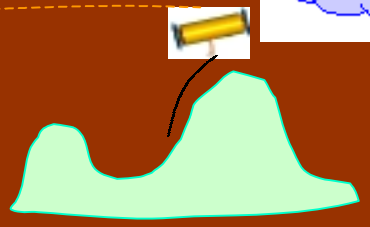


Communications, control, planning, reconfiguration, navigation and scout launching

Sensor data

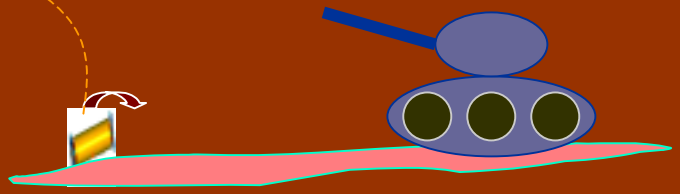
Ranger

CPU, GPS, sensors, actuators, communications array



(1)

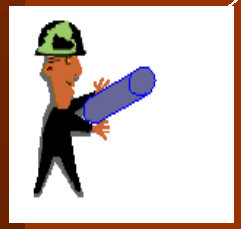
M203 grenade launcher



(2)

Length: 600mm

Coordination & data routing



Scout

(1) Audio Sensor
(2) Vibration Monitor
(3) Video Reconnaissance Module

Diameter: 40mm

Magnetometer, tiltmeter

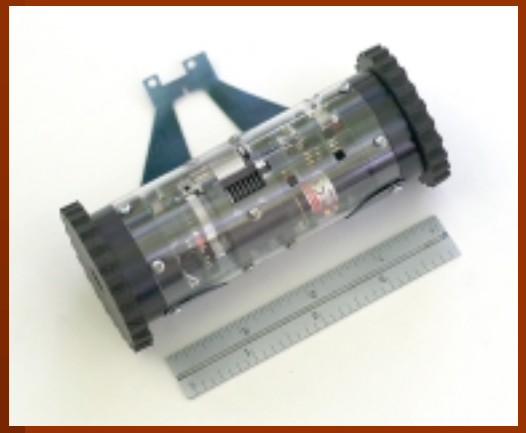
Video

(3)

T.I. Ranger-Scout: Control and Coordination of a Complex, Heterogeneous Distributed Robotic System

T.I. Scout: Design and Functionality of the Scout, Miniaturization of the Scout Hardware Peripherals, Sensors Design

Scout 2000 vs. Scout 1999

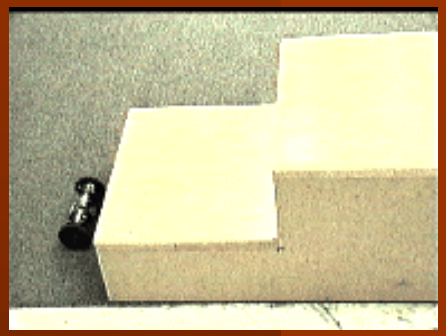


Scout 2000

Scout 1999

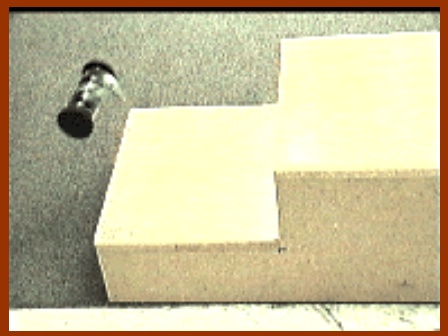
- **Complete electronic and electrical redesign**
- **Significantly improved power management**
- **Encoders have been added to the drive motors.**
- **The internal components have all been modularized to decrease assembly and repair time from hours to minutes.**
- **The jumping spring and winching motor have been improved to increase overall mechanical efficiency and the height of jumps.**

Scout Jumping Trial

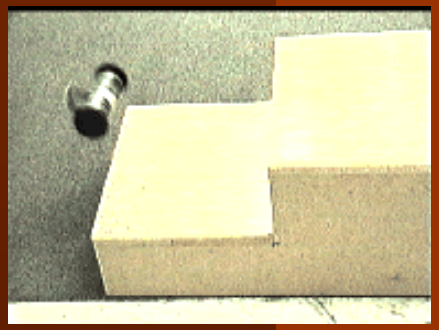


(a)

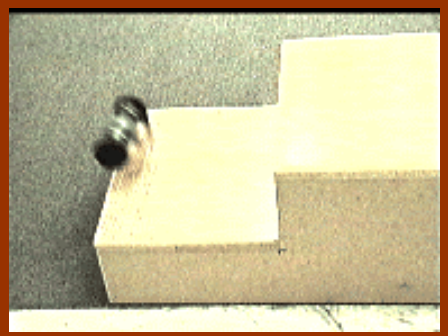
(b)



(c)



(d)



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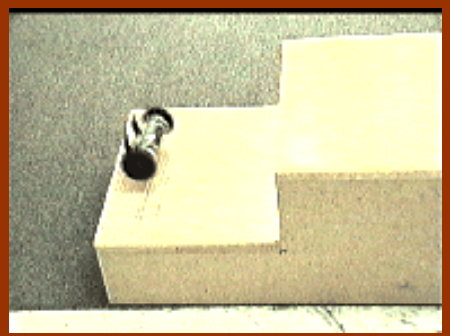
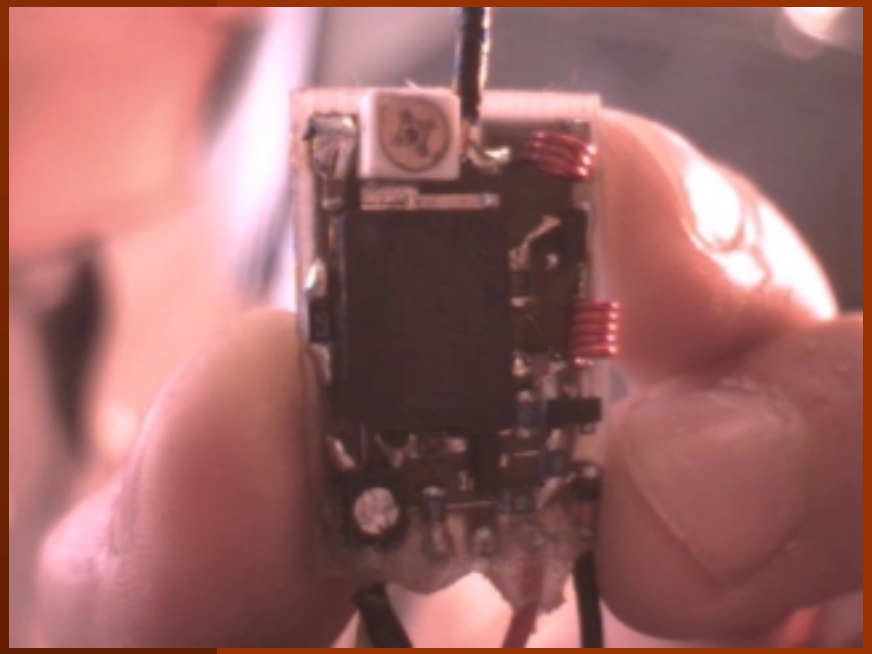


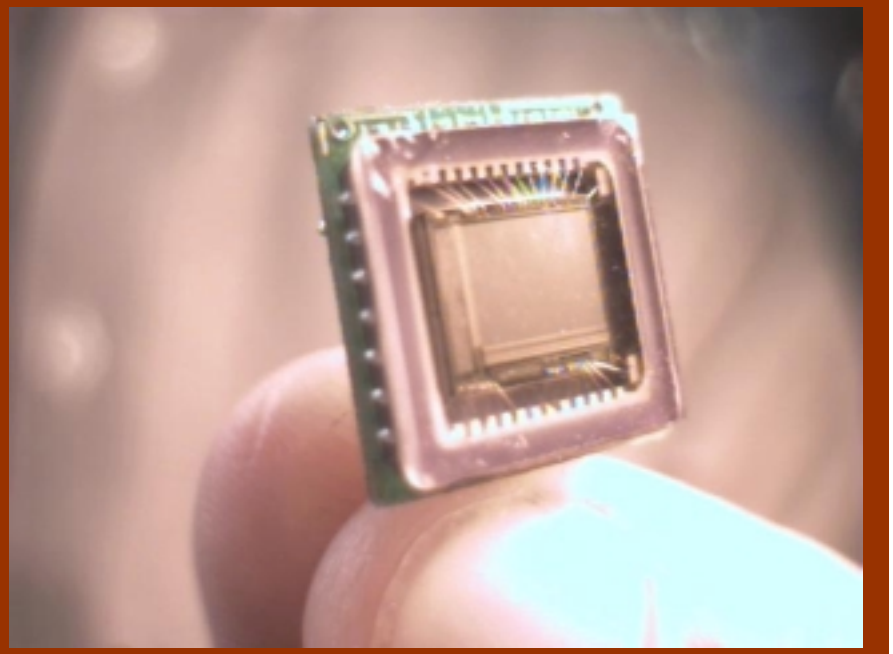
(f)

Video Reconnaissance Module

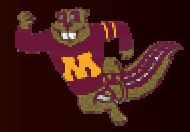
VIDEO TRANSMITTER



VIDEO SENSOR



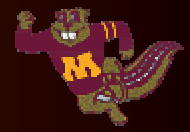
Video Reconnaissance Module



SENSOR

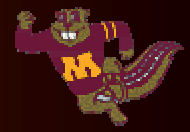
- **1/2” B/W CMOS single-chip video sensor with automatic gain control**
- **240 TV Lines resolution**
- **Miniature pinhole lens**
- **Power Consumption: 180 mW (20 mA @ 9 VDC)**
- **Video Output: 30 frames/s analog video**

Video Reconnaissance Module



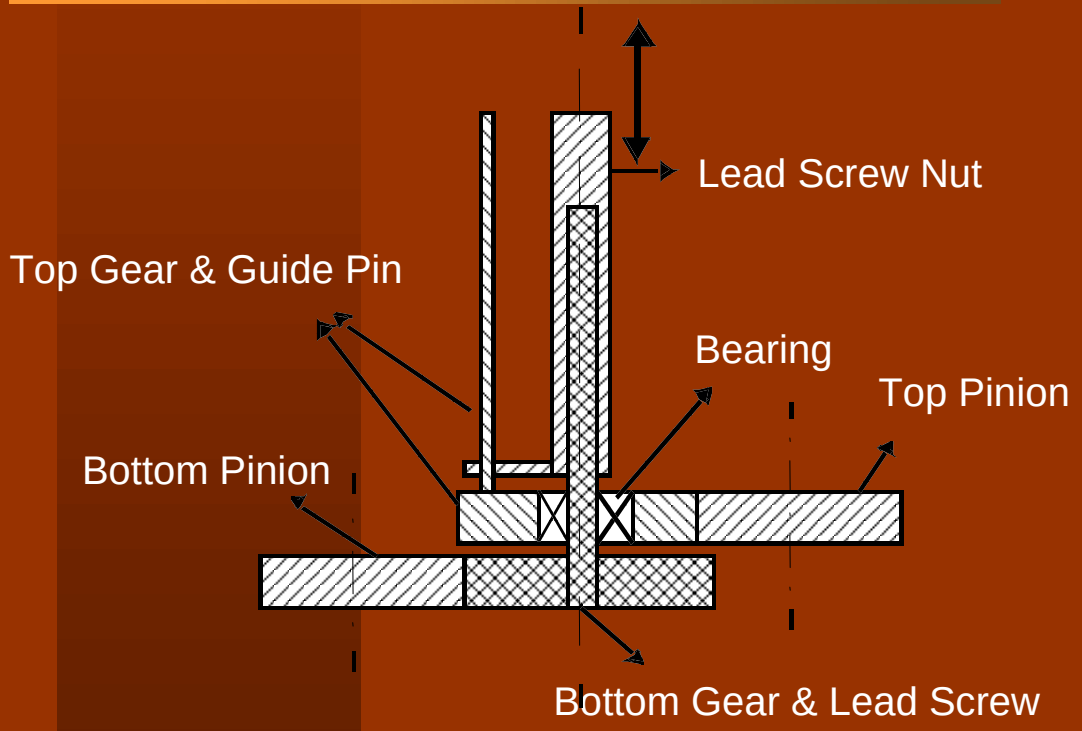
PAN-TILT MECHANISM

Design Challenges



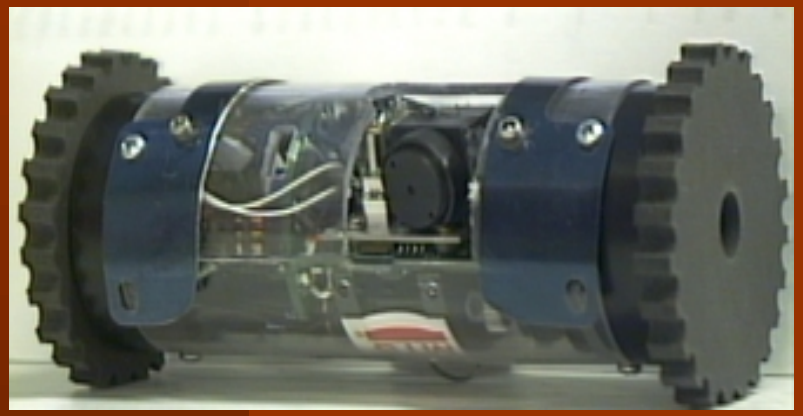
- **Extremely limited payload volume.**
- **The structure should resist dynamic forces.**
- **The camera needs pan, tilt and raise up/down motions.**
- **Unlike common pan-tilt cameras, none of the actuators move with the camera, significantly easing cable management in the confined payload volume and increasing overall reliability.**

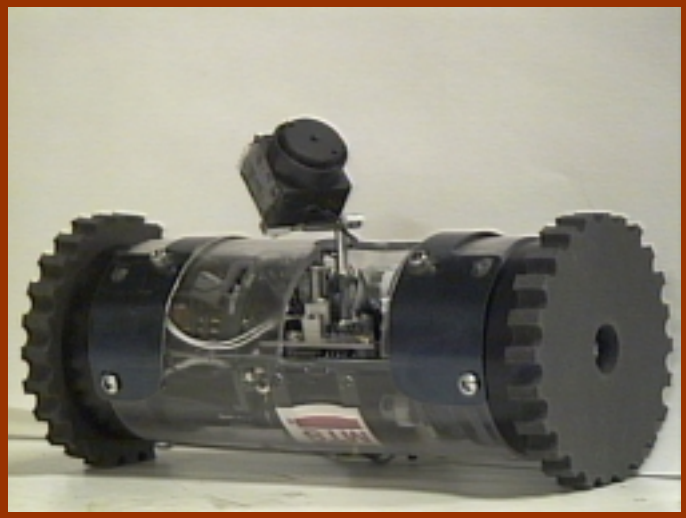
Mechanism Operation



- **A lead screw and a guide pin for the lead screw nut are actuated independently by two actuators. The lead screw nut will either go up and down or rotate around its axis. The axial motion of the nut is used in a tendon drive to tilt the camera while also raising it up. The rotation of the nut pans the camera.**

Scout with the Pan-Tilt Camera System

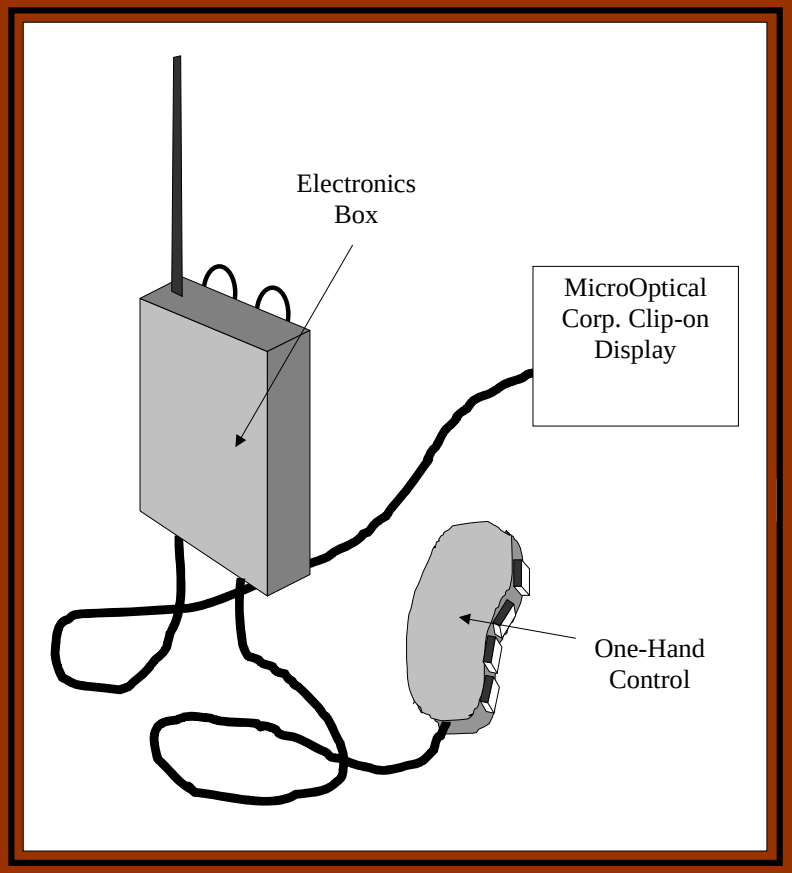




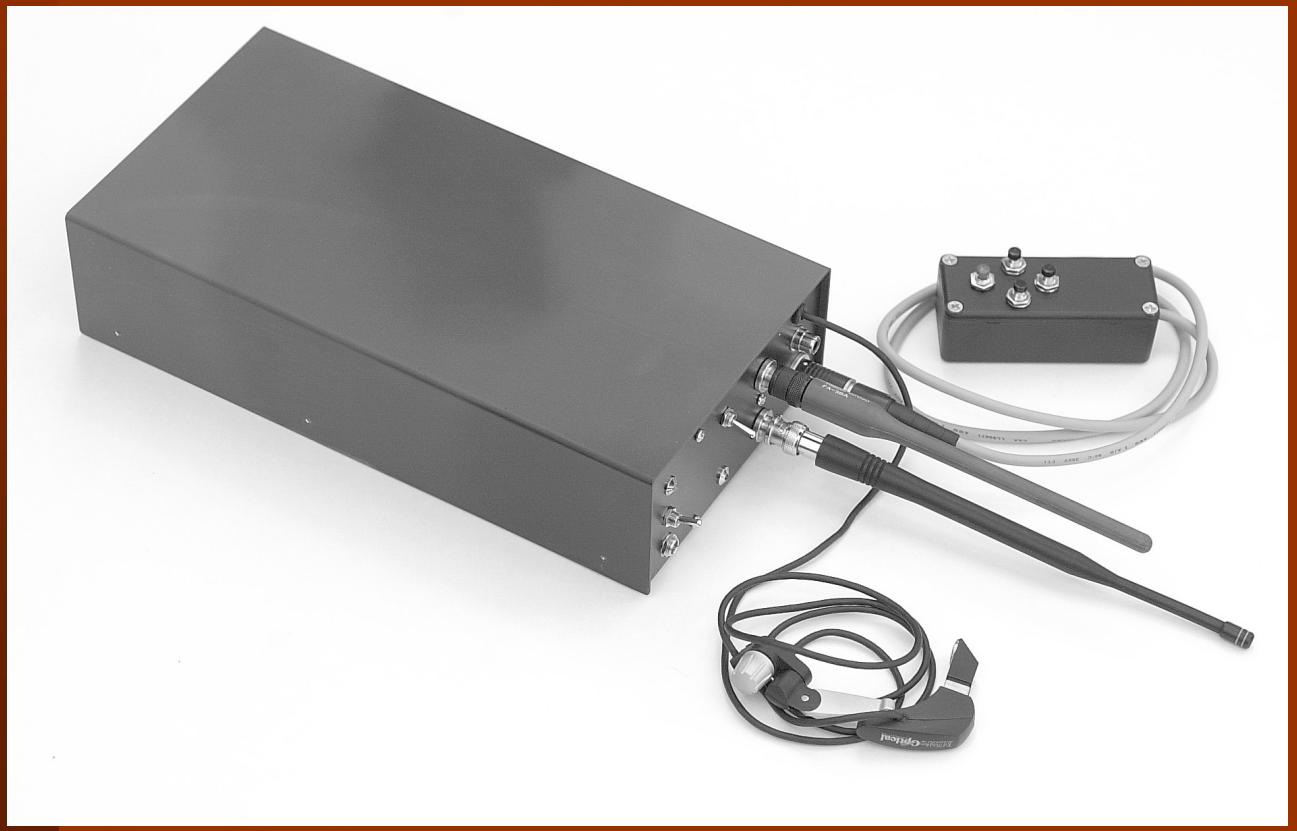
Motion Detection and Tracking

A computer vision algorithm was written to detect motion in the field of view and automatically track the center of motion.

MOUT-Cam: Scout User Interface



MOUT-Cam Controller



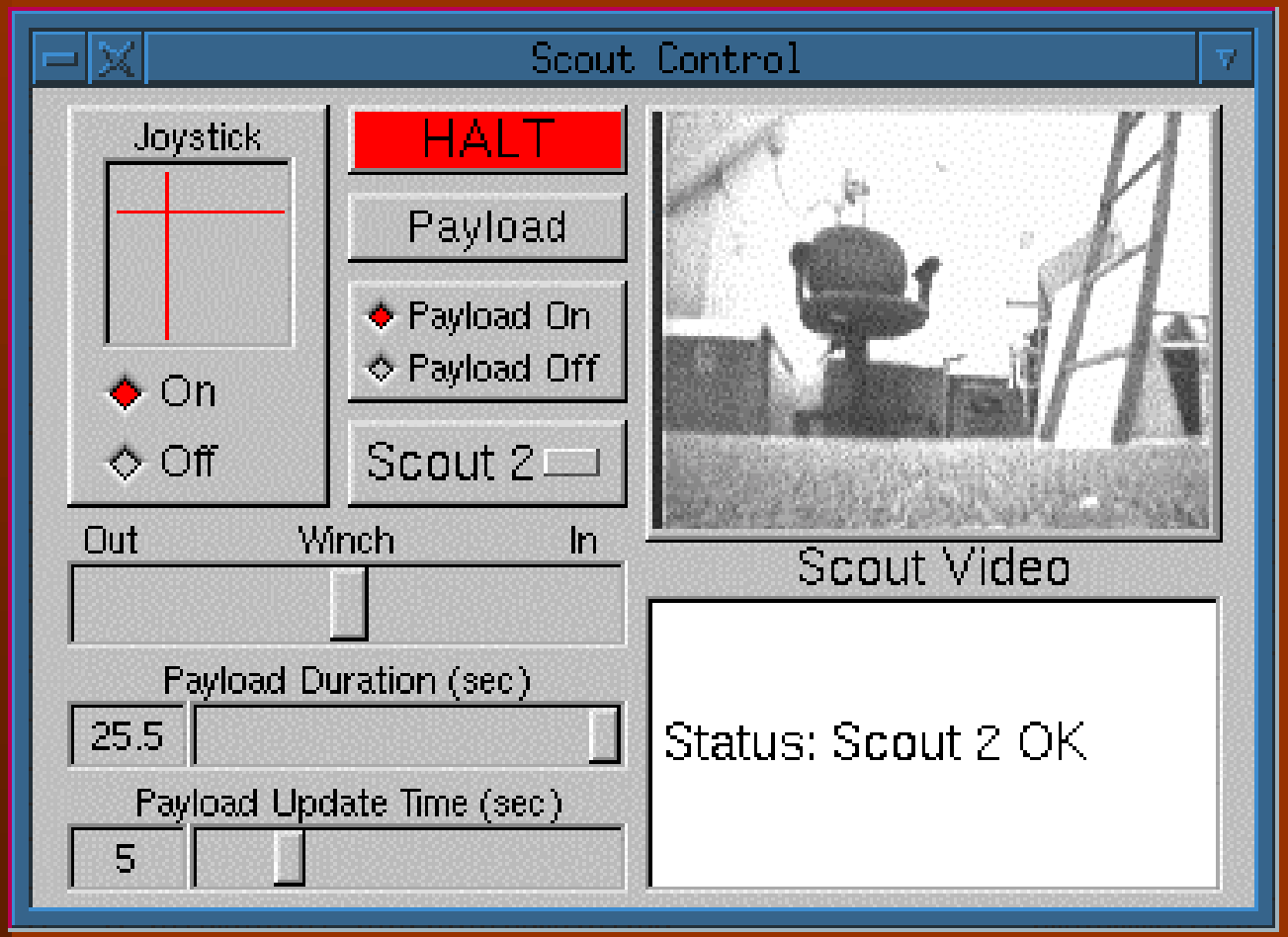
MOUT-Cam Viewer

MOUT-Cam

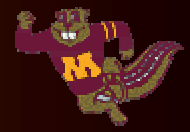
PDA interface

Joystick

User Interfaces



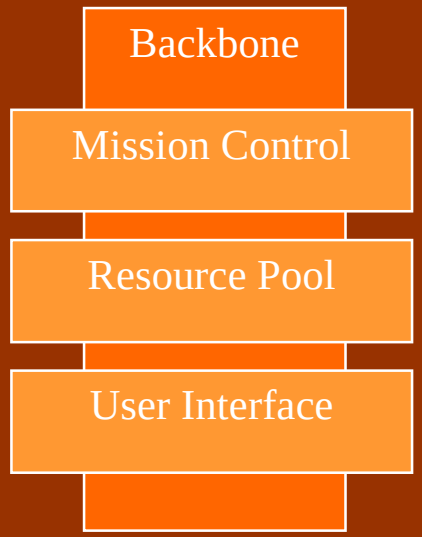
Software Design Goals



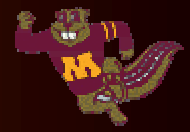
- **Distributed control**
- **Fault-tolerance**
- **Rapid system design**
- **Maximized resource exploitation**
- **Prioritized tasks**

Software Implementation

- **CORBA**
- **XML**
- **C++**



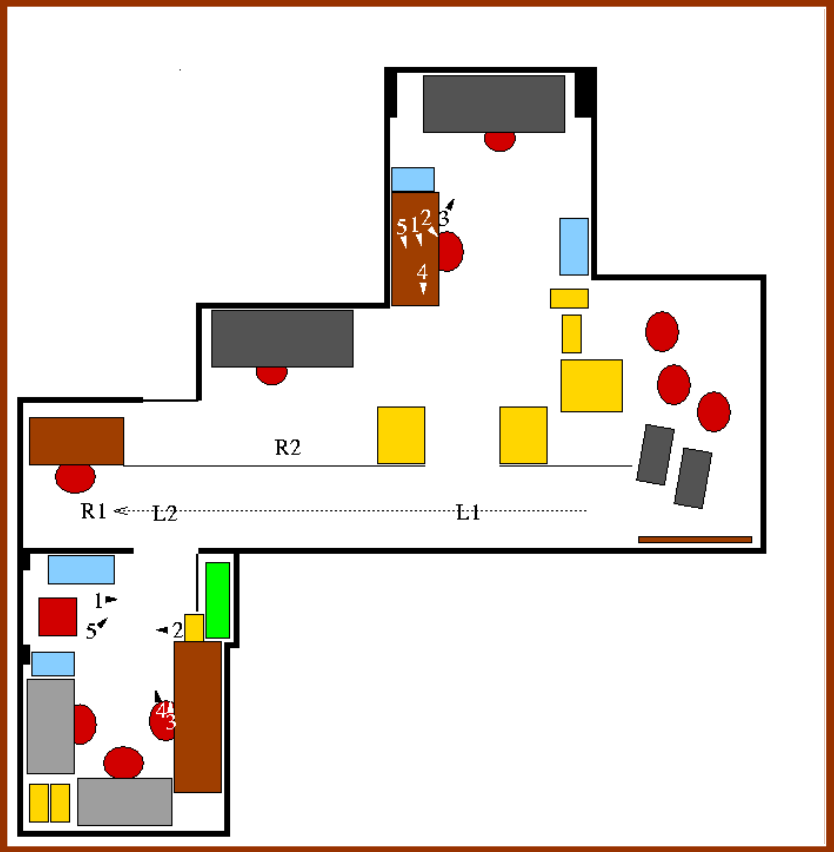
Mission Control



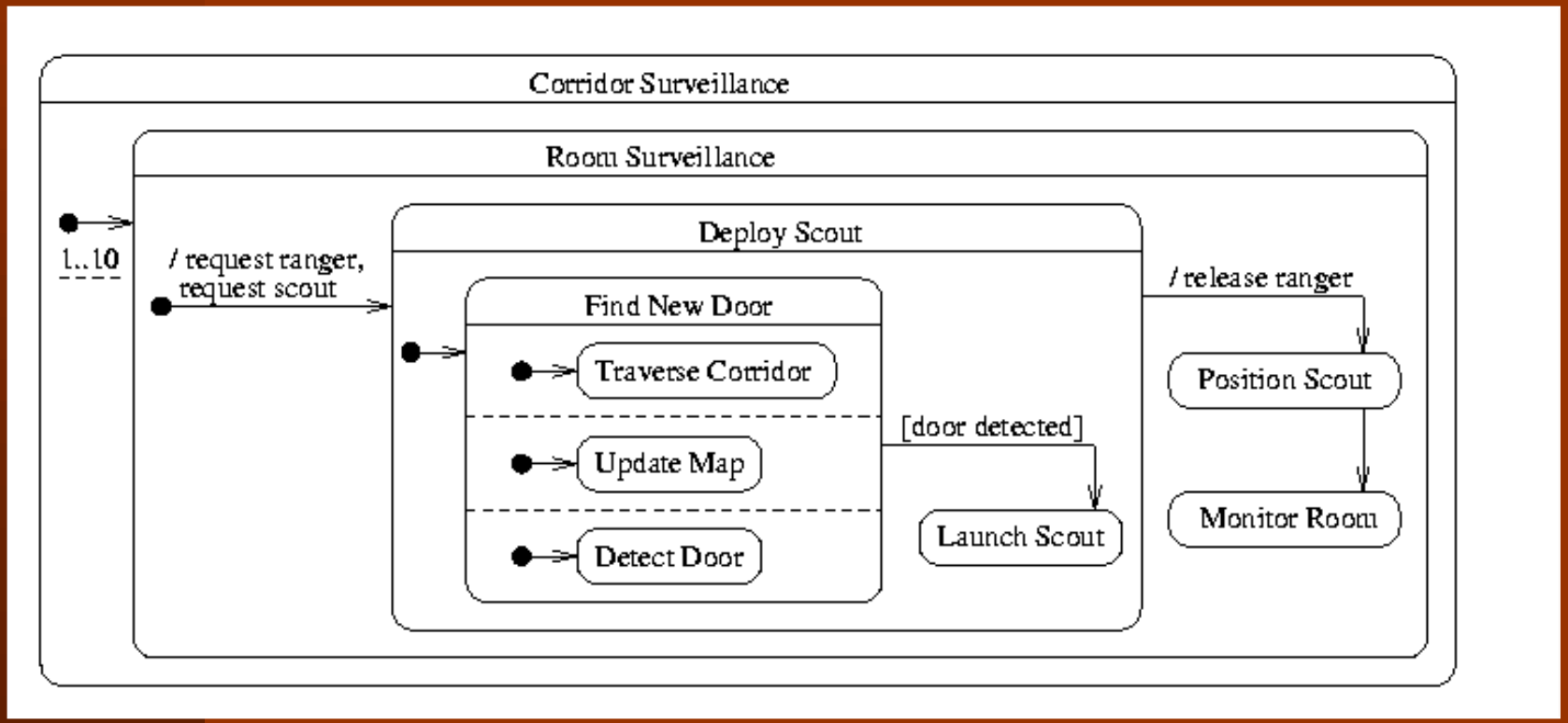
- **“Brain”**
- **Prioritized behaviors**
- **Decomposition**
- **Parallel execution**

Example Mission

- Surveillance system
- Heterogeneous robot team
- Large number of robots
- Parallel execution



Surveillance Mission



The Rangers

Real World Interface ATRV-Jr

- Length = 65 cm
- Width = 62 cm
- Height = 36 cm
- Weight = 50 kg
- Speed = 1.5 m/sec
- Payload = 25 kg
- Battery life = 3-6 hrs
- Computer = 233 MHz Pentium
- Network = 2.4 GHz wireless ethernet @ 2Mbps

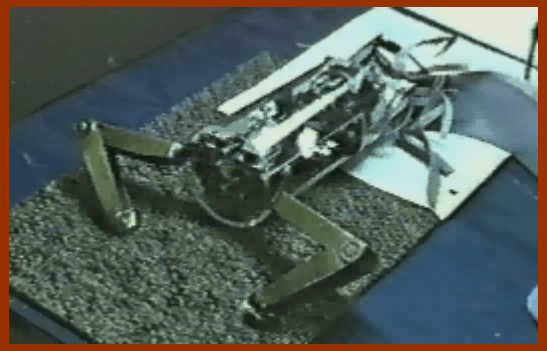
Scout Deployment Unit

Left View

Front View

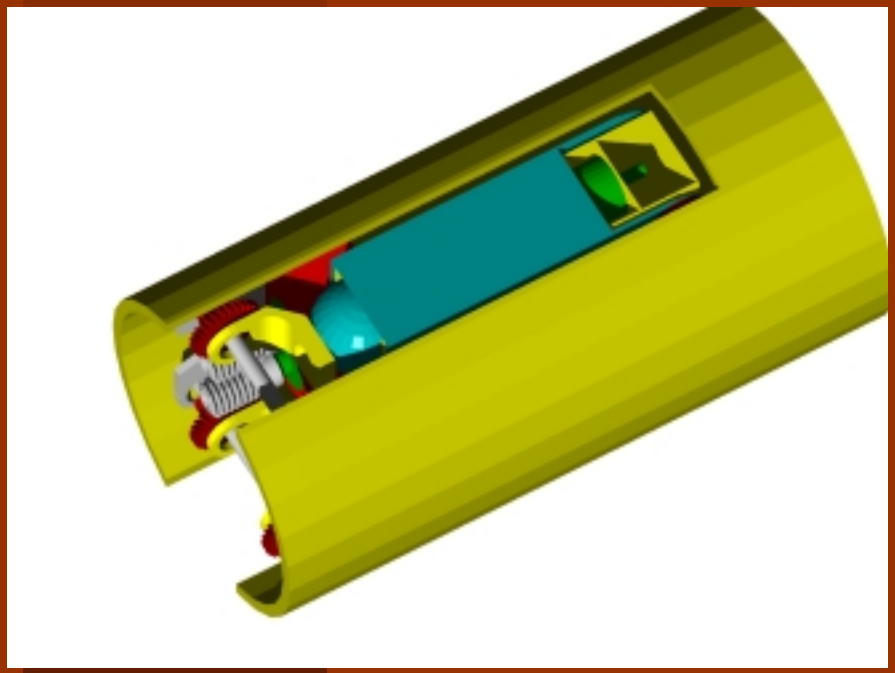
TerminatorBot - Alternate Scout

- **Two 3-DoF arms that stow inside body**
- **Dual-use arms for both locomotion and manipulation**
- **Four locomotion gait classes:**
  - **“Swimming” gaits (dry land)**
  - **Narrow passage gait (no wider than body)**
  - **“Bumpy wheel” rolling gait**
  - **“Body-roll” dynamic gait**

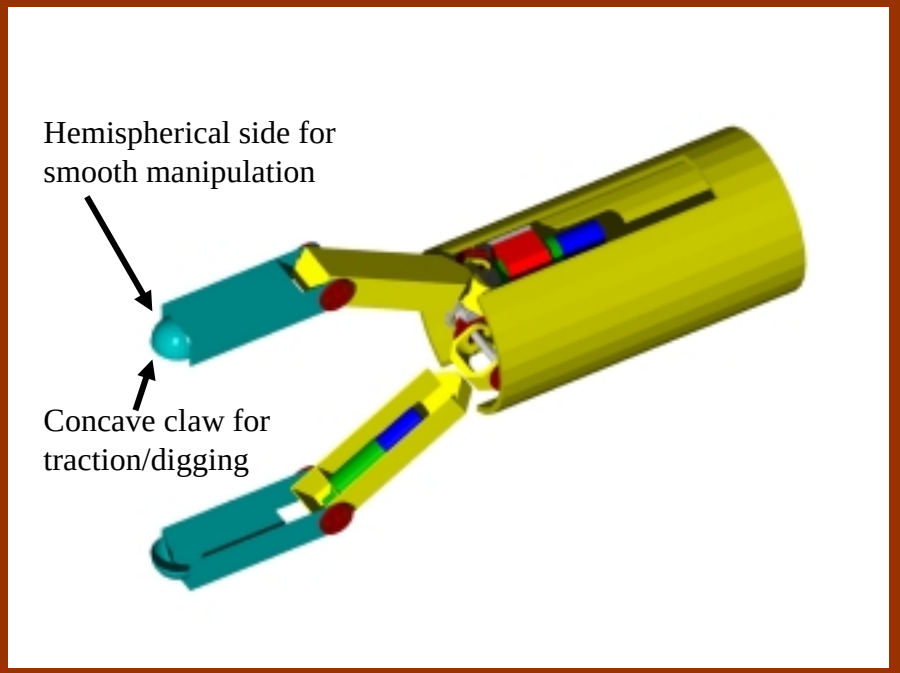


TerminatorBot Form Factor

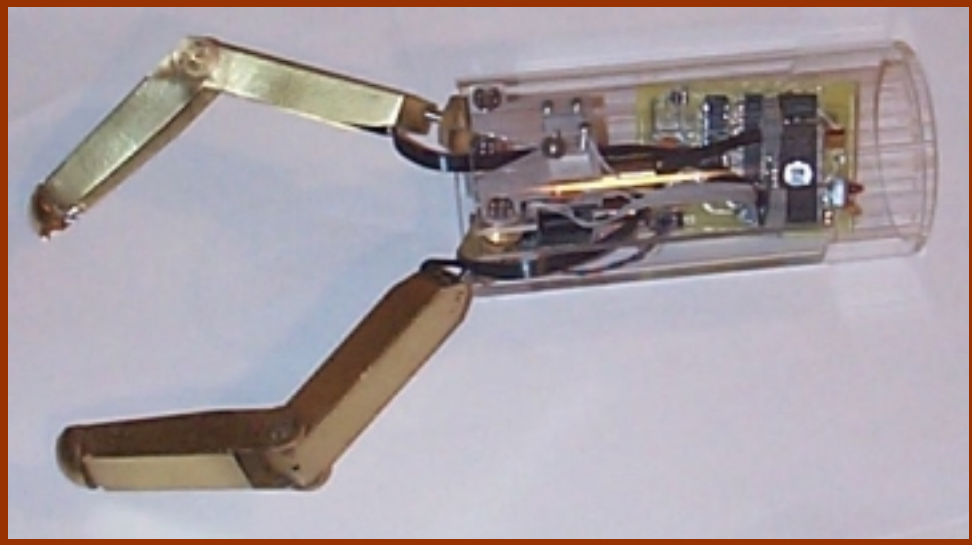
Stowed Configuration



Deployed Configuration

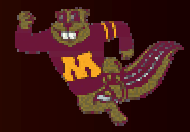


TerminatorBot Prototype



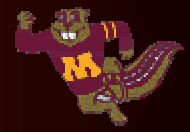
- 1st prototype is 75 mm in diameter (approx. 2x scale)
- Self-contained microcontroller for joint-level control
- Tethered for cartesian control (manipulation, perceptual servoing)

General Innovation Items



- Design and functionality of the scouts
- Design of the ranger-scout system (launching, communication, navigation)
- Simple control and communication primitives that can be reconfigured for a variety of robot behaviors
- Development of a large (44 agents) heterogeneous distributed robotic system based on these scalable, reconfigurable behaviors and physical components
- Miniaturization of the scout hardware peripherals (e.g. sensing, communication, etc.) required innovation.

Conclusions



- **Scout has proved to be a successful design**
- **Redesigned scout has long life and increased capabilities**
- **Various user interfaces have been developed**
- **Ranger-scout collaboration evolved to a useful level**

Acknowledgement

This material is based upon work supported by the Defense Advanced Research Projects Agency, MTO ("Distributed Robotics" Program), ARPA Order No. G155, Program Code No. 8H20, Issued by DARPA/CMD under Contract

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